12-2018

A View of the Bubonic Plague from the Perspective of Ibn Battuta using GIS

Luis Miguel Gutierrez Salines

University of Redlands

A View of the Bubonic Plague from the Perspective

of

Ibn Battuta Using GIS

A Major Individual Project submitted in partial satisfaction of the requirements
for the degree of Master of Science in Geographic Information Systems

by

Luis Miguel Gutierrez Salinas

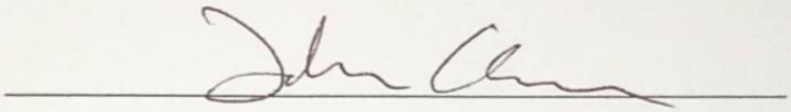
Douglas Flewelling, Ph.D., Committee Chair

John Glover, Ph.D.

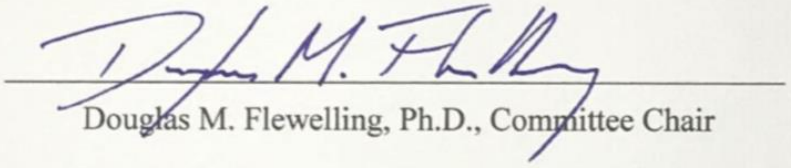
December 2018

A View of the Bubonic Plague from the Perspective of Ibn Battuta Using GIS

The report of Luis Miguel Gutierrez Salinas is approved.



John Glover, Ph.D.



Douglas M. Flewelling, Ph.D., Committee Chair

December 2018

Acknowledgements

In Loving Memory of My Mother

Maria Magdalena Gutierrez Salinas

July 1971 – March 2019

My life, my education, and my accomplishments would not have been possible without the never-ending support from my father Miguel and my mother Magdalena. They are my strength and my inspiration. I would also like to thank my sister Viris and my brother Juan for always being there for me when they've seen that I am stressed out and offered support. These past two years I have learned a great deal about GIS and about working professionally and I couldn't have done this without the help of Dr. Flewelling, Dr. Ren, Dr. Ma, Dr. Kumler and all the Esri staff. A special thank you to Dr. Flewelling who helped me develop the database in this project and guided me throughout my MIP. I would also like to give a special thanks to Dr. John Glover who provided the historical expertise for my project and for having influenced me, as far back as my freshman year of college, to pursue my love of history and maps. Thank you all.

Para mis padres,

Papá y mamá, gracias por todos sus sacrificios y trabajo para darnos a Viri, Juan, y a mí una vida mejor. Siempre tuve sus grandes esfuerzos y sacrificios en mi mente durante todos mis años de estudio. Este proyecto y este reconocimiento se los dedico a ustedes. Gracias.

Abstract

A View of the Bubonic Plague from the Perspective of Ibn Battuta Using GIS

by

Luis Miguel Gutierrez Salinas

The purpose of this project was to develop a spatial lens through which to see the historical interaction between 14th century traveler Abu Abdallah Muhammad Ibn Battuta and the bubonic plague. The secondary purpose for this project is to show how Geographic Information Systems can greatly contribute in the archiving and retrieval of historical data and the study of history overall. The primary objective was to develop an editable database that would contain spatial and historical information about Ibn Battuta and the bubonic plague. The secondary objective of this project was to upload the database on to ArcGIS Pro and develop a geodatabase that included all the data collected. The final objective of this project was to develop a time-slider enabled map from the geodatabase that would show Ibn Battuta's travels and the bubonic plague's advancement over time with an emphasis on any interaction they may have had. The results focus on Ibn Battuta's arrival to the Middle East and his encounter with the bubonic plague in modern day Syria. This was shown by combining the spatial data found on both actors, Ibn Battuta and the bubonic plague, and having both sets of data interact with one another via the time-slider enabled map.

Table of Contents

Chapter 1 – Introduction 1

1.1 Client 1
1.2 Problem Statement 2
1.3 Proposed Solution 3
1.3.1 Goals and Objectives 3
1.3.2 Scope 4
1.3.3 Methods 4
1.4 Audience 5
1.5 Overview of the Rest of this Report 5

Chapter 2 – Background and Literature Review 7

2.1 GIS in History Today 7
2.2 Applying GIS to History 7
2.3 History Within the Framework of GIS 8
2.4 Ibn Battuta 8
2.5 The Bubonic Plague 8
2.6 Summary 9

Chapter 3 – Systems Analysis and Design 11

3.1 Problem Statement 11
3.2 Requirements Analysis 11
3.3 System Design 12
3.4 Project Plan 13
3.5 Summary 14

Chapter 4 – Database Design 15

4.1 Introduction 15
4.2 Conceptual Data Model 15
4.3 Logical Data Model 16
4.4 Data Sources 19
4.5 Data Collection Methods 19
4.6 Summary 19

Chapter 5 – Implementation 21

5.1 Introduction 21
5.2 Data Acquisition 21
5.3 Database Development 22
5.4 Editing the Database 22
5.5 Geodatabase Development 24
5.6 Summary 25

Chapter 6 – Results and Analysis..... 27
Chapter 7 – Conclusions and Future Work..... 29
Works Cited ……..31

Table of Figures

Figure 1-1: Modern boundaries of regions visited by Ibn Battuta…….….2
Figure 3-1: System design…….18
Figure 4-1: Preliminary conceptual data model……...…..…22
Figure 5-1: Ibn Battuta's travels using 14th century trade routes……...……31

List of Tables

Table 1-1: Project Functional Requirements 11

Table 1-2: Project Non-Functional Requirements 12

Table 4-1: Sources…….……23

Table 4-2: Time Indexing Table……...…….24

Table 4-3: Places……25

Chapter 1 – Introduction

Epidemics such as the bubonic plague, typhus fever and cholera are ever present dangers faced by humanity. In the present day, however, we can track these epidemics with greater accuracy, which help us to prevent further spreads of these highly contagious illnesses by using Geographic Information Systems. Today's knowledge of GIS can also be implemented to solve the questions of the past. This project focused on the widespread devastation of the bubonic plague, better known as the Black Death. During the time of the bubonic plague in the 14th century there was a traveler and scholar named Abu Abdallah Muhammad Ibn Battuta, from Tangier, Morocco, who visited North Africa, the Middle East, Asia, and Eastern Europe, along with many other places. He wrote one of the best-known first-hand accounts of many of the major cities devastated by the plague and it is through his perspective that I analyzed the spread of the plague from East Asia through the Middle East and across to Europe by using GIS to track the historical movement of the bubonic plague. My client, and expert on this topic, was Dr. John Glover of the History Department at the University of Redlands. He helped to make sure my research, pertaining to dates and locations, was accurate to produce the best data possible.

1.1 Client

The client for this project was Dr. John Glover, professor in the History Department at the University of Redlands in Redlands, California. He is an expert in West Africa, Islam and European imperialism. The issue that was addressed in this project was using modern GIS mapping technology to create a database of historical locations visited by scholar and explorer Ibn Battuta and locations affected by the bubonic plague during the 14th century. Dr. Glover introduced the idea of using Ibn Battuta's primary source descriptions to analyze the spread and reach of the plague throughout the Silk Road and beyond because of Ibn Battuta's extensive travels and experiences as shown in Figure 1-1.

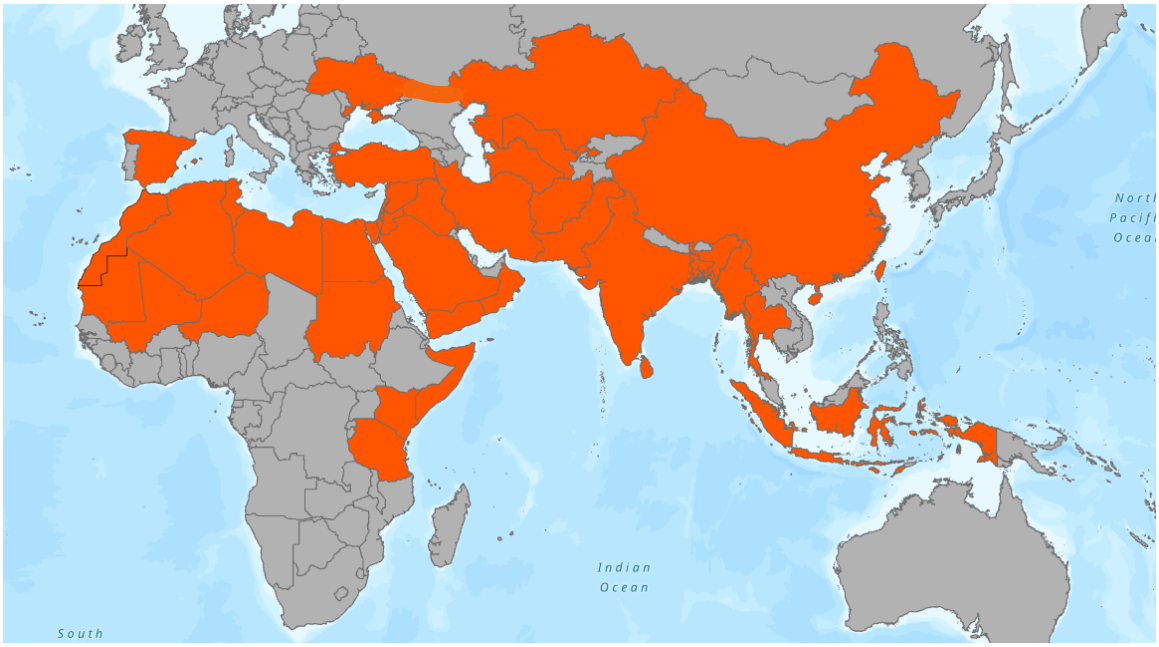


Figure 1-1: Modern boundaries of regions visited by Ibn Battuta

1.2 Problem Statement

The bubonic plague was an epidemic that engulfed most of Asia, the Middle East, Eastern and Western Europe, and North Africa during the 14th century. It is well established today that the bubonic plague spread to such large distances because of the existence of a complex network of trade routes that span from Asia to Western Europe (Benedictow, 2006). The spatial component to this topic was to use GIS to map the locations affected by the plague using Ibn Battuta's first-hand descriptions along with other reputable sources. Once the data was collected, a time-slider enabled map was created to show the advancement of the plague along with Ibn Battuta's travels. Analysis was performed to further show the magnitude of the bubonic plague in the areas most affected. Dr. Glover introduced the idea of viewing the bubonic plague from the perspective of Ibn Battuta since he is well documented to have traveled to many of the major areas most affected by the plague therefore making Ibn Battuta a very credible source of reference for times and locations that were implemented into the data to create a more accurate map of the affected areas. For historical research purposes, a database was created that broke the information down into subsections by source, infection, event, place, journey, and actor to make all the information easier to query and easy to update. The focus of the project was to be able to access all aspects of the historical information as efficiently as possible. Through this project, future generations will better understand the historical significance of the bubonic plague to better comprehend current and future epidemics around the world and know how to more effectively deal with them by using GIS. By learning from the past, we can create a better future for all.

1.3 Proposed Solution

The first step to mapping the historical locations through which Ibn Battuta and the plague traveled was to research through the best available historical data from that area in the 14th century. Dr. Glover recommended works by Dr. Ross E. Dunn, Professor Emeritus at San Diego State University in California (Dunn, 2005). I used these sources along with others related to trade routes and the bubonic plague to collect location data and historical information on Ibn Battuta, the plague and the specific locations they reached. I then gathered all this information on Excel spreadsheets in database formats to make the most efficient database possible. The first step in making the database was to break all the information down into subsections by source, infection, event, place, journey, and actor to make all the information easier to query and easy to update. Next, I uploaded my database to ArcGIS Pro to visualize all my different location points and to provide added functionality. Functionality was added in the way the different points were displayed on the map. For example, as Ibn Battuta's journey begins, the symbols start as small circles with a particular color scheme. As Ibn Battuta's journey continues, the size of the circles and the color scheme begins to change to better illustrate the difference in locations. This makes it easier to tell apart one location from another when the locations are in close proximity from each other. I then used the time-slider function to manipulate my dates by location to make my map come alive over the period of time of Ibn Battuta's travels and the plague's sinister journey from Asia to Europe throughout the 14th century.

1.3.1 Goals and Objectives

One of the primary goals of this project was to show how GIS can be used to answer spatial questions of the past. Most of the earth's human history has occurred on the surface of the earth, making GIS especially effective in analyzing past and present human spatial information. Everything from expanding and shrinking empires to volcanic eruptions to global warming can be tracked and analyzed using GIS because all these historical events bring forth very spatial questions. In order to continue their mission of teaching the lessons of the past, historians must adapt to new technologies and take advantage of GIS to reach new generations of historians, and the general public. A map is worth much more than a thousand words because one very well-made map can teach someone a lesson in minutes that would otherwise take them weeks or months to learn by reading. Maps can reach much larger audiences. The main objectives for this project were as follows:

Objective 1) The first objective was to collect as much data as possible about the bubonic plague and Ibn Battuta's travels while noting similarities in paths taken as well as noticing any specific trends.

Objective 2) The second objective was to take all those locations and first-hand accounts and illustrate them spatially on a map. Dr. Glover specifically mentioned that he wanted a time-slider map that would show the bubonic plague and Ibn Battuta's progression over time.

1.3.2 Scope

The scope of this project was based on the time during which Ibn Battuta and the bubonic plague intercepted each other in the Middle East. However, in order to perform further analysis on the plague and the reasons for its rapid expansion, I also added data that traces its path back to its accepted source of origin in the Asian steppes around modern day Mongolia. When it came to the actual physical aspect of my project, I was responsible for gathering historical spatial information about Ibn Battuta's travels and the path of the plague and organizing it onto an Excel based database. Once the database was completed, I uploaded the database to ArcPro and enabled the time slider tool based on the year to illustrate Ibn Battuta's movement alongside that of the bubonic plague, slowly moving towards each other until they converged in the Middle East. The exact time range was from 1325 to 1353, from the beginning of Ibn Battuta's voyage to the end of the bubonic plague. However, due to limited time and in order to stay within the scope of the main topic of this project, I had to omit 21 years of Ibn Battuta's main journey, which is most of his journey. This is because the intended focus was on Ibn Battuta's interaction with the bubonic plague, not Ibn Battuta's entire 20+ year journey. This, however, leaves room for further expansion of the project for a later time.

1.3.3 Methods

This project was designed to be partially a History research project since all the data needed to create the database would have to be researched and documented. My client, Dr. Glover, suggested Dr. Ross E. Dunn as one of my main sources because of his extensive work on Ibn Battuta and his travels (Dunn, 2005). Most of the research on Ibn Battuta came from one of Ross Dunn's best-known works, *The Adventures of Ibn Battuta: A Muslim Traveler of the 14th Century*. This book carefully describes Ibn Battuta's travels from the time Ibn Battuta left his home in Morocco in 1325, across North Africa, the Middle East, Asia, and Europe, and ends describing his death in around 1368. What made this book specifically useful is that it broke Ibn Battuta's travels into sections, providing detailed descriptions of the cities where he traveled, along with a map illustrating step by step where he went. In order to support my hypothesis that the bubonic plague spread through the Silk Road and other trade routes, a portal service was used that shows all the known trade routes on land and sea used during the time of the plague in the 14th century.

Once the best sources available were found, a functioning database was developed with the help of Dr. Flewelling. The database was made in Excel spreadsheets and broke down into locations by location identification number, modern city names, modern regions, latitude and longitude, the year when the location was visited or affected by the bubonic plague and a brief description of the importance of the location. Other tables were made that connected sources, paths, journeys and other important information back to the main spreadsheet which contained the spatial information. The idea was to be able to make querying the database as efficient as possible.

1.4 Audience

This project is intended for historians, professors or students, with little to no experience using GIS software. One of the themes that I addressed in this project was how valuable GIS is for historians because of the spatial and analytical characteristics of history. All historians could greatly benefit from the use of GIS in their research because history in itself is spatial; it happened on the surface of the earth or another celestial body, like the moon or Mars. However, because of the lack of technical jargon in the project, it can be easily understood by your typical undergraduate student.

1.5 Overview of the Rest of this Report

The following chapters will describe in detail the steps that were taken to plan, develop and execute this project. Chapter 2 will go more into detail on the background of the project and a literature review. Chapter 3 discusses the systems analysis and design of the overall project. Chapter 4 talks about the way the database was designed and its primary purposes. Chapters 5 and 6 describe the implementation and results of the final product while reflecting on the final outcome of the project. Finally, chapter 7 discusses how this project could possibly be expanded upon in the future.

Chapter 2 – Background and Literature Review

Despite the fact that GIS is widely available today, most historians seem to ignore or devalue the benefits that modern spatial technologies can contribute to their field as hinted by Alexander von Lunen and Charles Travis (Von Lunen and Travis, 2013). History and geography have the ability to coexist because every historical event has in some way happened in a geographic location, so history as a discipline has much to benefit from GIS. This chapter will first discuss how GIS has the ability to revolutionize the way new generations of historians are engaged in the study of history. Next, the chapter discusses how GIS can make archival and retrieval of historical data much more efficient. At the end of the chapter, the concept of how to think spatially within history is introduced to better understand the way history fits within the framework of GIS.

2.1 GIS in History Today

The unfortunate current truth about GIS in the study of history is that even though GIS is now widely available, historians are not yet implementing GIS into their research and curriculums (Von Lunen and Travis, 2013). As stated by Alexander von Lunen and Charles Travis, "It may be attributed to the wider lack of quantitative methods in history curricula these days…computers are rarely used by historians other than for word processing and literature databases" (Von Lunen and Travis, 2013, pp. v). In other words, historians are still not comfortable implementing modern technologies to their historical work because they lack understanding of GIS. This is very unfortunate taking into consideration that younger generations with inclinations towards new and attractive technologies such as computers, smartphones, and now even virtual and augmented reality, may become disengaged with the study of history simply because it is still being presented to them in an antiquated manner. GIS is the future of the study of history. In a very literal sense, most of everything that has occurred in human history has occurred on the surface of the earth or even on the surface of the moon, but on the surface of a celestial body nonetheless, and this is why GIS must become a part of the future of the study of history.

2.2 Applying GIS to History

The way in which we view our world, but most importantly the way we see ourselves within it, has drastically changed over time as revolutionary technologies have become available. Through the late 1800s and early 1900s, the invention of the radio, the telephone, automobiles and planes dramatically changed the way humans viewed distances and ultimately reshaped the view of ourselves on the earth (Bodenhamer, 2013). Today's revolutionary spatial technology is GIS, a tool that allows us to once again reshape the way we see ourselves on the earth. GIS now gives us more control than ever over managing not only what is being created and changed on the surface of the earth in the present, but also can be used to better comprehend what used to be on the surface of the earth in the past.

By harnessing the spatial knowledge of the past, we can help pave a better future for generations to come by learning from the past and avoiding the mistakes made by previous generations. As stated by D.J. Peuquet, "associating temporal information with locations allows the history of individual locations and sets of locations to be traced and compared" (Peuquet, 1999, pp. 97). By giving existing locations information about their state in previous periods of time, GIS can provide history with endless flexibility to archive and retrieve information accessible in seconds that in the past would have taken hours or even days to obtain.

2.3 History Within the Framework of GIS

In order to understand GIS from a historical perspective, we have to first know how to think about historical spatial information. As stated by Detlev Mares and Wolfgang Moschek, "Past events are easily placed within a spatial framework of reference that remains blurred and unspecified, as if space was a preexisting entity without its own history and with unchanging features and points of reference" (Mares and Moschek, 2013, pp. 59). In other words, we have to think of historical data the same way we think of modern spatial data, as constantly broadening and evolving by the effects of nature and people. This is a method that cannot be applied in an average history class, where lessons are taught and learned as snapshots in time often omitting the spatial changes that occurred throughout history. Often these spatial changes add logic to the reason why history unfolded the way it did making history easier to understand and even making it predictable, thus making those lessons learned by studying spatial history more useful in our daily lives (Mares and Moschek, 2013).

2.4 Ibn Battuta

Abu Abdallah Muhammad ibn Battuta was born on February 25th, 1304 in Tangier, Morocco into a family of scholars of Islamic law. He was a descendent of the Berber tribe called the Lawata (Dunn, 2005). He began to study Islamic law at a young age and wanted to travel the Islamic world in order to find the best teachers available and someday hopefully obtain a high-ranking position as a judge (Dunn, 2005). Ibn Battuta departed on his journey on June 14th, 1325 and headed to Mecca in modern day Saudi Arabia to perform the hajj, which is a holy pilgrimage all Muslims are required to make (Dunn, 2005). This began Ibn Battuta's 20+ year journey that would take him across the Muslim world and beyond, giving present day historians a glimpse into the past to the places he visited, the people he encountered, and wrote about in his journals later compiled into what he called his Rihla or Journey (Dunn, 2005).

2.5 The Bubonic Plague

The bubonic plague or Black Death is believed to have originated in Central Asia in the mid-1330s (Benedictow, 2006). However, it is best known to have been active in China and then across to the Middle East and Europe between 1346 and 1353 (Benedictow, 2006). Bubonic plague is a highly infectious disease caused by a bacterium called Yersinia Pestis (Benedictow, 2006). During the 14th century, the bubonic plague was spread by fleas that lived on the fur of black rats. These rats easily climbed on transport

ships carrying goods across the ocean from Asia, to the Middle East, and on to Europe through the Mediterranean. The complex network of land and sea trade routes made it easy for the plague to spread from one side of the known world to the other (Dunn, 2005). To show how the complex network of land and sea trade routes influenced the spread of the plague, a map service obtained from portal in ArcGIS Pro was used to turn on and off on the time-slider enabled map as needed to make references to plague stricken locations and places where Ibn Battuta traveled (Maps.com).

2.6 Summary

The purpose of this project is to provide an engaging way to view Ibn Battuta's travels and his encounter and interaction with the bubonic plague in the 14th century. Ibn Battuta's extensive travels and written accounts of his journey help to illustrate an image of the devastation of the bubonic plague. At the heart of this topic is the idea that there are endless applications for GIS within the field of history. GIS has the ability to expand and revolutionize the way historical information is archived and retrieved making it more accessible and useful as a tool for research. The following chapter will describe how these principals are applied to this project through its system analysis and design.

Chapter 3 – Systems Analysis and Design

3.1 Problem Statement

This chapter will go over the requirements of the project and introduce a system design based on these requirements. The problem this project addresses is being able to use the available historical resources, written in English, to solve a historical question: did Ibn Battuta encounter the bubonic plague in his 20+ year journey across the old world? This project focused primarily on the interactions Ibn Battuta had with the plague, so almost all of Ibn Battuta's main journey had to be omitted since his encounter with the bubonic plague did not occur until a few years before his return home. The way this problem was addressed was by creating a database of historical information based on the best available resources which were then compiled in Excel spreadsheets by topic. The spreadsheets were then uploaded to ArcGIS Pro where they were individually joined to one another to create a geodatabase for the purpose of querying and historical research. Excel was chosen as the foundation of the database because of its editing capabilities and functionality. This database can easily be edited allowing the database to grow over time to make it more useful and functional as a historical research tool.

3.2 Requirements Analysis

The first functional requirement of the project was that the final map must show the locations through which Ibn Battuta traveled in relation to the bubonic plague. This requirement's focus was to answer the question stated earlier, did Ibn Battuta encounter the plague? If yes, where did he encounter the plague and document any relevant information on his interaction with the plague. The second functional requirement works in conjunction with the first requirement, the map must show the locations affected by the bubonic plague in relation to Ibn Battuta. The third functional requirement applies to both of the earlier requirements, the map must contain the best possible time information of Ibn Battuta and the plague because the final product will be a time-slider enabled map that will be able to show Ibn Battuta's interaction with the plague overtime.

Table 1-1: Project Functional Requirements

Functional Requirements	**Descriptions**
Ibn Battuta	-Final map must show the locations through which Ibn Battuta traveled in relation to the bubonic plague.
Bubonic Plague	-Map must show the locations affected by the bubonic plague in relation to Ibn Battuta's travels.
Time-Slider Map	-Must obtain the best possible time information about Ibn Battuta and the bubonic plague to create a time-slider enabled map.

As a non-functional requirement, Dr. Glover requested that the project be compatible with ArcGIS Pro and/or ArcGIS Online. He also requested that the database be editable so that the project can be expanded upon as time goes by.

Table 1-2: Project Non-Functional Requirements

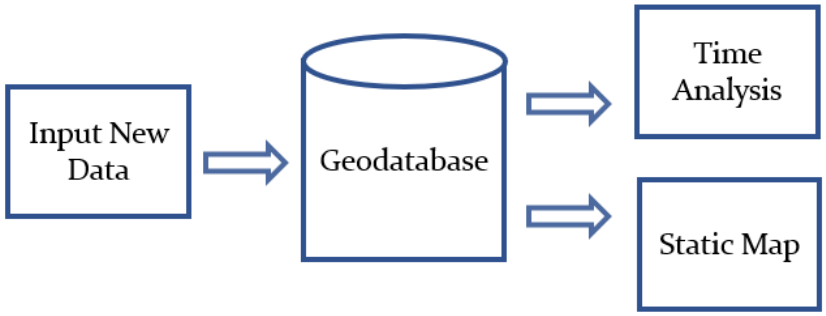
Non-Functional Requirements	**Descriptions**
Compatibility	-The database must be compatible with ArcGIS Pro and/or ArcGIS Online.
Editability	- The database must be editable.

3.3 System Design

The system design was created around the idea that it could be used by undergraduate students or anyone with a limited GIS background. The idea is that a student can use the project and expand on the database relatively easily. One of the major components of the project, and possibly the most important, is the database. The database is composed of multiple Excel spreadsheets. Each spreadsheet represents a specific part of the data about either Ibn Battuta or the bubonic plague. For example, one particular spreadsheet is solely dedicated to places visited by Ibn Battuta, while another spreadsheet only contains source information of the sources where the data about Ibn Battuta was found. This separation of subjects was ultimately designed to make the final geodatabase easier to query once integrated into ArcGIS Pro.

The next major component was the geodatabase built in ArcGIS Pro, where the Excel database was hosted. This geodatabase contains a map service of historical trade routes used by Ibn Battuta during his travels because they were the safest methods of transportation at the time. This map service also helps as a reference to the user because it is believed that the trade routes significantly influenced the spread of the plague across Asia to the Middle East and on to Europe. The geodatabase is essentially the face of the project and the main method of user interface, so making it user friendly was a major part of the overall project. The system design can be seen in Figure 3-1 below.

Figure 3-1: System Design



3.4 Project Plan

When Dr. Glover was first contacted about the project, the original plan was to track only Ibn Battuta's travels since his 20-year journey had taken him to a considerable part of the known world at the time. The idea was to simply track everywhere he had gone throughout his life. However, there wouldn't be very much to analyze from Ibn Battuta's travels alone, so Dr. Glover introduced the idea of tracking Ibn Battuta's travels while tracking the path by which the bubonic plague spread. Historically, Ibn Battuta ended up surrounded by the plague when he reached the town of Homs, on his way back to Damascus, after returning from a trip to Aleppo in modern day Syria (Dunn, 2005, p.270). This makes Ibn Battuta one of the best first-hand accounts of the bubonic plague in the 14th century. This would allow for more spatial analytical data to build the database and more information to analyze in the geodatabase.

The most time-consuming task to perform was actually doing research and finding the data. Building the database for this project essentially became a history research project. The team collaborated with Dr. Glover to find the most reputable resources on the topics of Ibn Battuta and the bubonic plague. When dealing with 700+ year old data, it's very easy to come across incorrect data and mistake it for accurate information, so multiple sources were checked to keep good quality control. As the deadline became fast approaching, the original plan of mapping all of Ibn Battuta's travels had to be re-evaluated since there simply wasn't enough time to create a detailed database of all of Ibn Battuta's 20+ year journey. In order to keep the overall project on schedule and within the original scope incorporating the bubonic plague, Ibn Battuta's travel data had to be limited to two major journeys. The first being his journey from his home in Morocco to his original visit to Mecca on Hajj between 1325 and 1326 (Dunn, 2005, pp. 30-49). The second part of his journey covered in this project is his return from Guangzhou, China to the Middle East when he finally encountered the bubonic plague in Syria between 1347 and 1349 (Dunn, 2005, pp. 30-49). A considerable portion of data had to be omitted in Ibn Battuta's journey simply because his travels were so extensive and his interaction with the plague didn't occur until the last years of his journey. The focus of the use of Ibn Battuta's travels in the first place was to highlight descriptions of the plague, so adding further details of Ibn Battuta's travels would have added little value to the main topic of his interactions with the bubonic plague.

Another major part of the project was actually organizing all the data collected into a functioning Excel-based database. To make the database more functional, data was separated into various spreadsheets depending on their topic. For example, one of the spreadsheets deals with only location information such as: the modern city name, the modern region where that city is located today, the year the event occurred and a brief description of its importance. Another spreadsheet breaks down Ibn Battuta's travels into smaller journeys which make it easier to query. All sources are on another separate spreadsheet joined to the location spreadsheet by its Location ID. These categorizations are all in an effort to make the database easier to query once uploaded into the geodatabase.

In the end, it was necessary to narrow down the scope of the overall project to be able to finish the project on schedule. The database provides a comprehensive look into Ibn Battuta's travels while highlighting the database's importance in describing the effects of the bubonic plague in the Middle East. Though the database omits a large part of Ibn Battuta's journey, it focuses on Ibn Battuta's encounter with the plague. Ibn Battuta's detailed descriptions illustrate the ferocity with which the plague engulfed major trade hubs across trade routes and major cities, and this is emphasized through the ancient trade routes map service that serves as a reference in the geodatabase.

3.5 Summary

This chapter went into detail describing the system design requirements and planning for this project. The functional and non-functional aspects of the project are described and how they all work together to form a user-friendly historical geodatabase. The most time-consuming aspect of this project was the data acquisition, which had to be researched independently. The historical data is then organized into a system of Excel spreadsheets that broke down the information into categories: locations, infections, sources and journeys. The final Excel database was then uploaded to a geodatabase in ArcGIS Pro, where the information can be queried and analyzed.

Chapter 4 – Database Design

4.1 Introduction

This chapter will focus on the database design of the project. We will go into detail on the conceptual data model and the reason why this type of model was chosen for this particular type of data. The following section will talk about the logical data model developed for this project based on its requirements as a historical geodatabase. Finally, we will discuss the way sources were obtained for this project and how data was extract and organized for database development.

4.2 Conceptual Data Model

For this historical research minded project, my client's requirements stated that he would like an interactive map that would accurately show the major locations which Muslim scholar and explorer Ibn Battuta visited with an emphasis on the locations where he encountered the bubonic plague. In addition, each point on the map should be attached to a database that contained location and time information. The time information was crucial because the final step of the project required that the map be time-slider enabled to show Ibn Battuta and the plague's progression over time. In order to make a database that appropriately included all the location and historical data about the places Ibn Battuta visited and the bubonic plague infected, a simple data model had to be made that could communicate with the different parts of the database with a location identification or an event identification. The categorization of data based on the specific type of information it contains, would make the final database easier to query and make it more efficient as an archival and retrieval tool for historical research. A preliminary conceptual data model that shows this method can be seen in Figure 4-1.

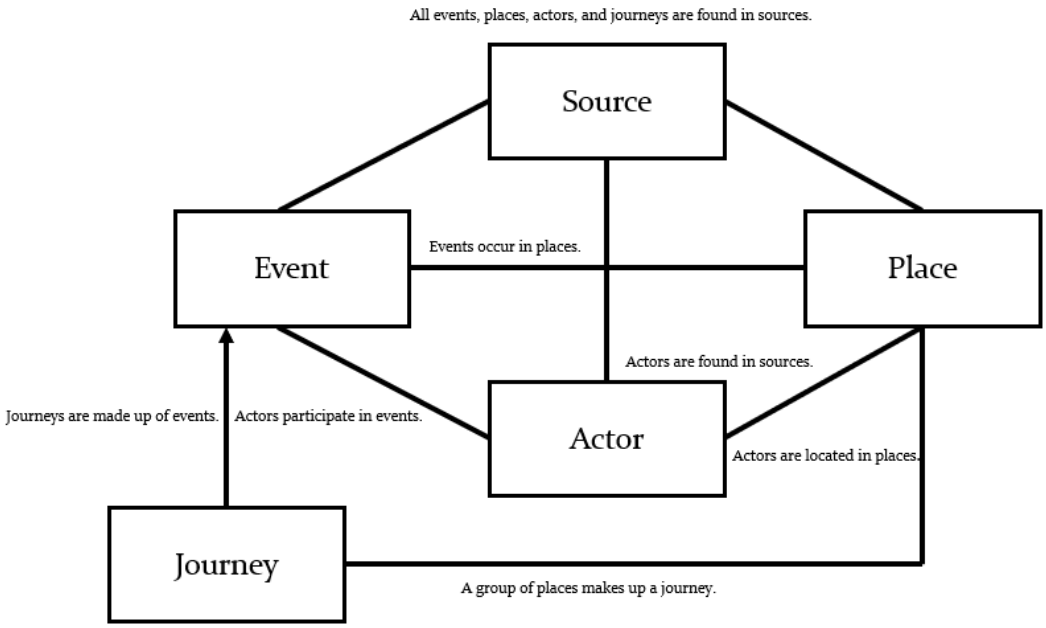


Figure 4-1 Preliminary Conceptual Data Model

4.3 Logical Data Model

In order to make a functioning database, the data had to be broken down to the specific type of information it contained which became: the sources, events, actors, places and journeys. Each of these topics formed a table that further broke down the information that was relevant to its main focus, for example, the sources table breaks down every aspect of my sources by location ID, author, year, chapter or section name, title and all of the book or other type of source's publishing info or website as shown on Table 4-1 below. This was done with historical research in mind so that all sited information can be traced back to the exact page where the information was found.

Table 4-1 Sources

LID	Author	Year	Chapter/Section Name	Title
1	Dunn, R.	2005	The Maghrib	The Adventures
2	Dunn, R.	2005	The Maghrib	The Adventures
3	Dunn, R.	2005	The Maghrib	The Adventures
4	Dunn, R.	2005	The Maghrib	The Adventures
5	Dunn, R.	2005	The Maghrib	The Adventures
6	Dunn, R.	2005	The Maghrib	The Adventures
7	Dunn, R.	2005	The Maghrib	The Adventures
8	Dunn, R.	2005	The Maghrib	The Adventures
9	Dunn, R.	2005	The Maghrib	The Adventures
10	Dunn, R.	2005	The Maghrib	The Adventures

Events were broken down by a location ID and an event ID, the idea for this is that locations where Ibn Battuta or the plague had a presence can be found by individual locations or by major events that happened in that location and may have included multiple locations. One of the most important modifications that had to be done in the events table was the addition of a time indexing column that helped to improve the representation of non-specific dates in historical data. Many of the events that were described in Ibn Battuta's travels did not have a specific date with a day, month and a year. This created a major issue when trying to represent dates in the time-slider map because ArcGIS Pro required uniform dates with a month, day and a year. The way the time indexing method works, is by allowing some of the non-specific time information like "early in June of 1347" to be represented in a manner that can be understood by ArcGIS Pro by allowing for controlled uncertainty usually between 1 to 4 months margin of error. For example, "early in June of 1347" would be represented as 13470607, or year, month, day, a format accepted by ArcGIS Pro. In other words, it is another way of indicating it occurred roughly on the first week of June. This method is very useful in the representation of historical data that is incomplete or uncertain. An example of this method being implemented in the database can be seen in Table 4-2 below.

Table 4-2 Time Indexing Table

LID	EID	Time_Index_+or-_4_Months	Year
1	1	13250614	1325
2	2	13250621	1325
3	3	13250714	1325
4	4	13250807	1325
5	5	13250814	1325
6	6	13250821	1325
7	7	13250907	1325
8	8	13250914	1325

9	9	13251107	1325
10	10	13251110	1325
11	11	13251114	1325
12	12	13251120	1325
13	13	13251121	1325
14	14	13251221	1325

The actors table represents people or entities that were center figures in major historical events such as Ibn Battuta and his travels or the black plague and the effect it had on the known world in the 14th century. The actors table allows for further addition of important people and entities to the database and each actor has its unique actor identification number that can be used during queries.

The places table provides the spatial information of the locations where Ibn Battuta and the bubonic plague traveled as shown in Table 4-3. Every location has its own unique location ID, a modern city name, modern region name (usually the present country name), and latitude and longitude information. Finally, the journey table connects the various locations that may have been part of a specific journey Ibn Battuta took, for example on his first journey from Morocco to Mecca. This table is designed to make it easier to find specific journeys Ibn Battuta may have taken when queried.

LID	Modern City Name	Modern Region Name	Latitude	Longitude
1	Tangier	Morocco	35.7595	-5.834
2	Tlemcen	Algeria	34.8884	-1.318
3	Miliana	Algeria	36.304685	2.2258039
4	Algiers	Algeria	36.7538	3.0588
5	Bijaya (Bejaia)	Algeria	36.7509	5.0567
6	Constantine	Algeria	36.3602	6.6424
7	Buna (Annaba)	Algeria	36.9265	7.7525
8	Tunis	Tunisia	36.8065	10.1815
9	Sousse	Tunisia	35.8245	10.6346
10	Sfax	Tunisia	34.7398	10.76
11	Gabes	Tunisia	33.8881	10.0975
12	Tripoli	Libya	32.8872	13.1913
13	Surt	Libya	31.185242	16.648355
14	Cyrenaica	Libya	31.000128	22.499972

Table 4-3 Places

4.4 Data Sources

The data used for this project were collected using sources provided by Dr. Glover. A large portion of the data regarding Ibn Battuta and his interaction with the bubonic plague came from a book by Dunn (2005). A variety of other reputable books, articles, and web-based sources were also used to gather information including: Benedictow (2006), Halsall (2001) and Peuquet (1991), among others.

4.5 Data Collection Methods

Since this project was very data collection heavy, an easy to use method had to be developed to organize data found which would make it easy to analyze and categorize. For this task, Microsoft Excel was used with the following categorizations: location ID, modern city name, modern region name, latitude, longitude, year, description, and source information. This was not intended to be the final database but simply a way to collect and organize the historical information as it was found during the collection process. However, this method made it much more convenient when developing the database later on in the project.

The results of the data collection were the points that symbolize the locations where Ibn Battuta and the plague traveled and the interactions that occurred between them. Each point contained all the data talked about earlier which was stored in a series of Excel spreadsheets.

4.6 Summary

This chapter began with a description of the conceptual data model for this project. We then discussed the logical data model and the actual structuring of the database which was based on the requirements of the project. In this particular section we talked about the time indexing method used during representation of historical data that is incomplete or uncertain, which is a method that could greatly benefit historians using GIS since historical information often has gaps. Finally, we discussed the way historical data was collected and some of the major sources used for the development of the database for this project.

Chapter 5 – Implementation

5.1 Introduction

This chapter will break down the steps through which this project was executed. It is important to highlight that the ultimate goal of this project was to create the foundations for a strong and practical geodatabase that will be used primarily for historical research purposes. In other words, it is meant to be simple enough that people with limited GIS capabilities can successfully use and expand on it over time.

5.2 Data Acquisition

The first step in developing this project was the gathering of reputable historical data with reference to Ibn Battuta's travels and the spread of the bubonic plague. To ensure the best available sources were used, the team enquired the opinion of Dr. John Glover of the History Department at the University of Redlands. Dr. Glover advised that one of the best sources available on Ibn Battuta was Dr. Ross E. Dunn of San Diego State University.

One of Professor Dunn's best works on Ibn Battuta is *The Adventures of Ibn Battuta: A Muslim Traveler of the 14th Century*. This book helped to create the majority of the research on Ibn Battuta's travels because of the chronological way in which it is written. Another very helpful feature of this book was that it broke down his 20+ year journey into smaller sections and illustrated the travels on a map with points indicating cities and towns visited in every section. After his travels, Ibn Battuta wrote a depiction of his journey throughout North Africa, the Middle East, Asia, and many other places in a book known as Ibn Battuta's Rihla or Ibn Battuta's Journey. Professor Dunn used this source to write *The Adventures of Ibn Battuta*, which makes it one of the most detailed accounts of Ibn Battuta's travels widely available today, almost 700 years after Ibn Battuta left Morocco on his legendary journey across the known world.

For the bubonic plague portion of the research, one of the main sources used was *The Black Death 1346-1353: The Complete History* by Ole J. Benedictow. This book summarizes all the locations where the plague spread by regions, so it made it easy to find the similarities between the plague's destruction and Ibn Battuta's travels. This was especially useful because the primary purpose of this project was to identify locations where both Ibn Battuta and the bubonic plague had reached.

Throughout the research portion of this project, special attention was given to finding the most specific locations as possible by the sources because of the spatial nature of this GIS project. When it came to specific coordinates of locations, Google Maps was used to find the most center location of every relevant city, town or other geographical marker to have the most precise locations possible. It must also be clarified that since the topic of this project has to do with events that took place almost 700 years ago, specific location information and names were not easy to come across, so we had to make do with non-specific locations and names of known modern places such as certain towns or cities still around today, as reference points.

Besides location information, brief descriptions of why those particular locations were relevant were also gathered, for example, what Ibn Battuta did in a specific location,

or the amount of people affected by the plague in a particular location. A detailed list of sources was kept from where all the information was found which will help in the development of the research purposes of this project. Since this project is designed primarily for undergraduate research, the source information will be available in the database and searchable down to a specific page within the source.

5.3 Database Development

One of the first requirements for this project was that it must be editable and expandable. This was carefully considered when deciding how to build the database. With this in mind, the team chose to develop the database from Excel spreadsheets. The general database design changed drastically from the beginning stages of the project to the final stages because, since this was meant to eventually be a geodatabase, it eventually had to be as easy to query as possible. Alterations to the Excel database were necessary, almost to the final stages of the project.

In the early stages of the project, the Excel based database consisted of one single spreadsheet with the following information: historical location, latitude, longitude, year, description, source, page and URL. This particular design was efficient only during the data collection stage of the project because it made it easy to gather and document all the information required in one single Excel spreadsheet. However, this design failed at the most important part of the project's mission which was to make it an actual database with the ability to query. After talking to Dr. Flewelling, he advised to break down all categories of information to make them easier to query.

Following Dr. Flewelling's advice, we broke down the single Excel spreadsheet into four different spreadsheets, each managing a specific part of the project: location, infection, source and journey. The location spreadsheet holds: a location ID to identify that particular location throughout the database, a modern city name, modern region name, latitude, longitude, the year the event took place, and a brief description of the relevance of that location. The infection spreadsheet holds: a location ID, location name, start month and year, end month and year, death toll, disease type, and the source where the information was found. The source spreadsheet breaks down all the source information down to all its basic parts: a location ID, author, year of publication, chapter or section name, title, page start, page end, publication city, publisher name, source citation in APA format, and URL when applicable. The journey spreadsheet breaks down Ibn Battuta's travels into sections depending on specific locations he wanted to reach such as reaching Mecca on hajj or his trip to China. These categorizations were done for the sole purpose of making the database as easy to query as possible.

5.4 Editing the Database

One of the primary requirements for this database was that it had to be editable in order to expand upon it in the future. The key to the database's flexibility is that it was built on Microsoft Excel. This means that if you are familiar with Excel spreadsheet's basic functions, editing the database is a simple process. For example, to add a new place you must first assign the location a unique identification number. This number will help you tell this particular new location from the many other places Ibn Battuta visited on his journeys. The way places are organized on the Excel database is currently in

chronological order. However, due to the unique identifier, the places can be written out on the database in any order, just make sure each place has an identification number or LID, a modern city name, modern region name meaning the current country it is located on, and accurate latitude and longitude.

To create a new event, make sure to include the unique LID created in the place section of the database, then give your new event a unique event ID or EID. Next comes a very important step. In order for ArcGIS or most GIS software to recognize dates of specific events, dates must be written in year, month, and day format in that order. For example, June 14th, 1325 would be written as 13250614, remembering that the total number of digits must be 8 in order to be recognized by most GIS software. After imputing your date information, you would then add your detailed description of the event created. Please note that this database is highly flexible and if the user would like to add an additional column for whatever type of information, this can easily be done just like adding a new column on any other Excel document.

Journeys are sections of Ibn Battuta's travels that were well defined. During his travels, Ibn Battuta took many detours and turns, but many parts of his journey were well defined, for example his journey from Tangier, Morocco to Mecca, Saudi Arabia on Hajj. To add a new journey, create a unique identification number for that particular journey. Next add the location where the journey began along with the start date. You can also note how precise your information is by indicating whether it was high or low precision. Next include the end location of the journey and an end date. In the final column you can include the reason for that particular journey.

A small but important section of the database allows you to add actors to the database. These are significant historical figures or entities that played important roles in Ibn Battuta's travels. Currently the only main actors in the database are Ibn Battuta and the bubonic plague. However, as the database is expanded upon and more research is done, this page can become an important tool for keeping track of influential people in Ibn Battuta's travels.

The infection section will allow you to keep track of information referring to specific locations where the bubonic plague was known to have been and the specific disease type along with other disease specific data such as the type of disease and death toll for that particular location. This section can be expanded upon to include more details pertaining to ways diseases impacted specific places.

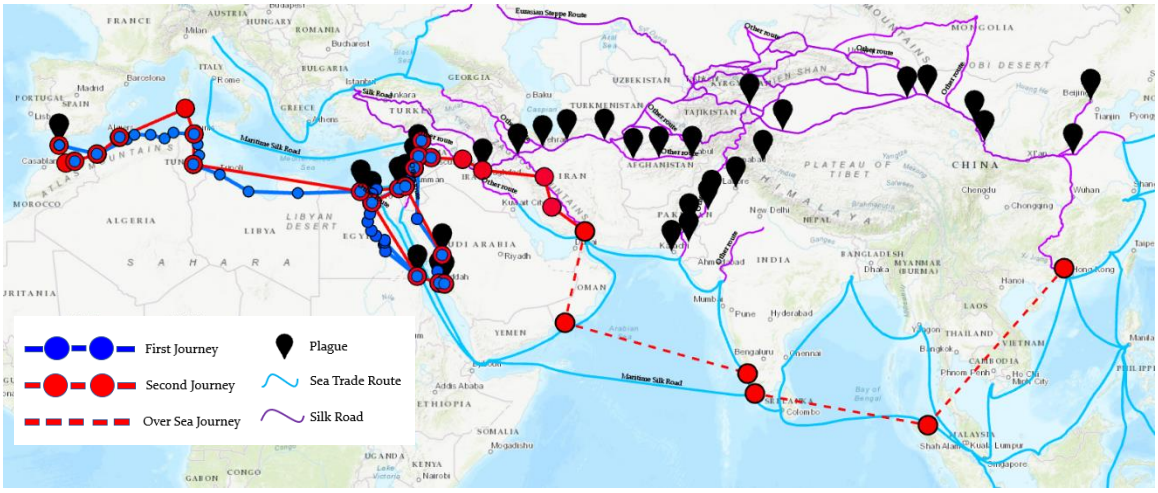
Finally, the most complex part of this database is where all your research information is stored, the source section. The source section is designed to break down all parts of your sources to make them easier to query and find. The sources were broken down based on what locations were found in that particular source, so the LID was used as the unique identifier for this section as well. Since the LID is attached to a specific location, add the latitude and longitude for that particular location found in that particular part of the source. Next, add the author's name in last name first initial format followed by the year the source was published. In the following columns you will document the source information such as section name, title, the number of the page where the information was found and other publication information. The database is already considerably populated so there will be many examples to follow.

5.5 Geodatabase Development

Once a functioning Excel based database was developed, it was uploaded into ArcGIS Pro. One of the requirements stated by my client, Dr. Glover, was that the database had to be compatible with ArcGIS Pro and, or ArcGIS Online. Once uploaded, the database appeared onto the map as points. Some of the points are static and symbolize potential locations where the black plague traveled through because they formed part of major trade routes at the time. The points that refer to Ibn Battuta's travels all have time data by the year, which means that when the time tool is used it will allow data to be manipulated based on when it happened in time.

It is believed that the bubonic plague spread from the Mongolian steppes, across the Middle East and all the way to Western Europe and North Africa because of the extensive trade network that economically and culturally united that part of the world during the 14th century (Dunn, 2005). For this reason, the team felt that it was a good idea to have some type of map reference to ancient trade routes working in conjunction with our own data to better highlight patterns that could support the theory that trade routes indeed had a major role in the spread of the plague as seen in Figure 5-1 below. This came in the form of a map service added through ArcGIS Pro's portal (Maps.com). However, before adding the map service the team inquired about its source to Dr. Glover and he approved.

Figure 5-1 Ibn Battuta's travels using 14th century trade routes



The next step to making the database into a fully functioning geodatabase was to start making connections between the different spreadsheets in my Excel database. By using the location IDs, a join connection was made between the location and infection spreadsheets. This will allow both spreadsheets to communicate with one another within the geodatabase. By using this method, all of the spreadsheets are able to communicate effectively with one another to make the geodatabase as easy to query as possible, making the user interface more effective and efficient.

The final step to completing the geodatabase was to adjust the time-slider portion of the geodatabase to effectively show all the data gathered in the most effective manner possible. The idea is that the information will pop up on the screen in chronological order, following Ibn Battuta's path from his departure from Tangier, Morocco to where he meets with the plague and then follows his path back home. The final touches were making sure the titles for all the layers and information boxes were appropriate and complete.

5.6 Summary

This chapter described in detail all the steps that were taken to plan, develop and execute this project from beginning to end. The first major step was data acquisition, where we described the major sources for the data and why the team chose to use these particular sources. Next, is a description of the early stages of the database, effective for collecting the data and having a simple and efficient way to keep track of data collected. Here we described a detailed set of instructions on how to expand upon the database by editing information and making data management more flexible within the database. We then described how the database had to be broken down into different categorizations to make it a true functioning database that would be easy to query once uploaded to ArcGIS Pro. Once uploaded into ArcGIS Pro, the database became a geodatabase with the proper joins to allow the information to be queried. We also discuss the use of a map service from ArcGIS Pro's portal to help as a reference to ancient trade routes to further show the connection between the spread of the bubonic plague and the complex network of trade routes during the 14^{th} century from Asia to Europe (Maps.com).

Chapter 6 – Results and Analysis

This chapter will describe the results of the project along with reflections regarding the steps taken to complete the various requirements. Like in most long-term projects, not everything came out exactly as planned in the beginning of the project. Project plans and details had to be altered in order to stay within the scope of the project and within deadlines.

The original plans and expectations for the project involved tracking down Ibn Battuta's entire 20+ year voyage, as well as to track any interactions he may have had with the bubonic plague. However, as research began to take up too much time and potentially causing major delays in the later parts of the project, the scope had to be narrowed in order to stay focused on Ibn Battuta's interactions with the bubonic plague while continuing to stay on schedule. This meant that about a 20-year portion of Ibn Battuta's travels would not be included in the database from 1327 to 1346 (Dunn, 2005). This created a considerable gap in the database that would later cause problems when rendering all the data into a time-slider map. Whenever the entire dataset was added to the map, there would be a 2-minute gap in the time-slider making it difficult to show the progression of the points over time effectively.

When the Excel based database was finally complete and ready to be made into a geodatabase, it was time to add the time-slider function to make the data come alive in an interactive form. However, it was quickly apparent that the giant gap in time created earlier was now literally creating a gap in the timing of the time-slider map, creating gaps that would last for minutes making the map difficult to watch. Since it is not possible to run two different time-sliders in a single layer, two individual maps had to be made with time-slider functions so that the individual time ranges could run effectively and with much greater detail. This allowed each point on the map to have more flexibility in between the other points during the time-slider function, making it more observable when the next point popped up on the map.

One of the most enjoyable parts of this project was researching historical data about Ibn Battuta and the bubonic plague. Dr. Glover was very helpful in guiding the team to very reputable sources like Dr. Ross Dunn, who's an expert in Ibn Battuta's travels. Even though data collection was the most time consuming and tedious part of this project, it was never tiring because there were new discoveries to add to the database every day making the search interesting as the database grew. Dr. Ross Dunn's book in particular was tremendously helpful in the overall development of the database (Dunn, 2005). Not only did Dunn's book read like a journal as Ibn Battuta trekked across most of the known world at the time, but Dunn also provided maps for every chapter of the book that outlined each part of the journey. The level of detail Dunn provided in his book was a major reassurance that let the team know that we were on the right track, which is important, taking into consideration that Ibn Battuta's journey took place almost 700 years ago.

When it came to the gathering of data into the Excel spreadsheets and categorizing everything as the database took shape, things went fairly well. The original reason why Excel was chosen as the foundation for the database was because of its simplicity and flexibility. Excel was able to accept coordinates and the other indexing

methods used to organize the database very effectively making data collection a simple procedure. Excel documents are also easy to upload onto ArcGIS Pro making that step take no time at all in the process of creating the geodatabase.

When Dr. Glover was first approached by the team about the topic of mapping Ibn Battuta's journey, he thought it was a very interesting and spatial idea. Being a history professor, Dr. Glover's insight and knowledge was needed to find the best available sources of data to track down Ibn Battuta's journey. It was also he who introduced the idea that we should focus on Ibn Battuta's interaction with the plague since it is widely accepted that Ibn Battuta came into contact with the bubonic plague somewhere in the Middle East. However, it was implied that we would be mapping Ibn Battuta's entire journey, which as mentioned earlier, did not go as originally planned. In order to stay on schedule and within the scope of the overall project, after tracking Ibn Battuta's first journey from his home in Tangier, Morocco to Mecca in modern day Saudi Arabia, we had to skip most of Ibn Battuta's 20-year journey to when he encountered the plague, creating a considerable gap in the data.

Despite the need to decrease the scope of the project, Dr. Glover still liked the results and suggested that the points on the map be made a bit more unique from one another in order to notice the more subtle and clustered points when running the time-slider tool. This was easily accomplished by adding unique values to all the points and assigning to them a wide variety of colors in continuation form. To make the individual points even more noticeable, points located in areas of higher concentration were manually inspected and were assigned colors that would better tell them apart from surrounding points. This was especially helpful during the public presentation of the project where a large amount of people needed to understand the time-slider map in a very short amount of time. Dr. Glover also liked the break down of the database into events, places, actors and sources because it makes the database easy to query for historical research purposes and to expand on the database as well.

In short, the project does everything it was intended to do from the beginning. The heart of the project is a simple database developed from various Excel spreadsheets. Information can easily be added to the database over time if needed such as adding new types of ancient plagues and diseases or even new actors for example Marco Polo or other significant people of the 14th century or simply completing Ibn Battuta's entire 20+ year journey, which unfortunately could not be added in its entirety. The flexibility provided to the database by ArcGIS Pro makes it easy to edit even the smallest detail of the user interface of the map. Nearly every part of the map can be changed to fit different audiences or purposes, and this is very useful when trying to reach a wider audience in any discipline.

Chapter 7 – Conclusions and Future Work

The purpose for this project was to develop a new way through which to see and use historical data. The subjects of this project were Moroccan traveler Ibn Battuta and his interaction with the bubonic plague during the 14th century. The first task was to gather spatial and historical data about Ibn Battuta and the bubonic plague and organize all the data in an editable database. Excel was chosen as the best platform for the database because of its flexibility and compatibility with ArcGIS Pro. Once the database was completed and all the different types of information were individually categorized, the database was uploaded to ArcGIS Pro. One by one the Excel spreadsheets that formed the database were uploaded to ArcGIS Pro and joins were made through ArcGIS Pro so that information would properly communicate when queried as a geodatabase. Finally, the time data within the geodatabase was given functionality via the time-slider tool in ArcGIS Pro and Ibn Battuta's journey to Mecca and his interaction with the plague became visible.

The main goal set by Dr. Glover of seeing the interaction between Ibn Battuta and the bubonic plague was accomplished. The time-slider clearly shows how Ibn Battuta encountered the plague between Homs and Damascus, in modern day Syria. This is supported by research in Dr. Ross Dunn's book, where Ibn Battuta describes the way the plague stopped the normal rhythm of life in the region surrounding Damascus (Dunn, 2005). This is shown in the second part of the time-slider map on Ibn Battuta's return journey from China between 1347 and 1348 (Dunn, 2005).

In the end, the overall functional requirements of the project were successfully met. The time-enabled map clearly shows the locations where Ibn Battuta traveled, as well as major points where the plague likely passed through and its interaction with Ibn Battuta. The database created from Excel spreadsheets is easily editable and able to be expanded upon. For the non-functional requirements, the database is able to be uploaded to ArcGIS Pro with just a few steps and can even be used with other non-Esri GIS software.

However, one of the implied requirements that Dr. Glover and I had originally talked about had to be altered in order to stay within scope and schedule of the overall project and that was the mapping of all of Ibn Battuta's journey. The original plan was to research all of Ibn Battuta's 20+ year journey, however, as research on Ibn Battuta's travels began, it became apparent that Ibn Battuta had not encountered the bubonic plague until almost the end of his 20+ year journey. This meant that if the research for his entire journey continued, the project as a whole would be veering off topic considerably so a redefining of the project scope had to be done to stay on topic and on schedule. However, this leaves the project open to future additions, to expand upon the database that has been created in this project.

From the beginning of this project, the idea was that the database would be editable to leave ample room for future improvement and expansion. One of the ways by which this project can be expanded upon is by completing Ibn Battuta's entire 20+ year journey. Ibn Battuta's journey took him to many places that went unmentioned in this

project to stay within the scope of the project, which was focused on Ibn Battuta's interaction with the bubonic plague. The final database is set up so that information pertaining to Ibn Battuta and his travels can be easily added onto the project to complete his entire journey. Another way this project can be expanded upon is by adding more actors to the database. As described earlier, actors can be any historical figures or events, such as the bubonic plague, who played major roles in world history. This project is set in the 14th century, which was a major time of trade and exploration so there are an endless number of actors who can be added on to the database such as other known explorers of that time or even kings or conquerors. The possibilities are great for expanding this project in the context of historical data. Yet another route to continue the expansion of this project can be in the documentation of ancient diseases. In the 14th century, humans still had a very limited knowledge of the way bacteria and diseases were formed and spread so illnesses would quickly ravish large populations because they simply didn't know how to contain epidemics (Dunn, 2005). This topic would greatly expand the infection section of the database. The ways by which this project can be expanded upon are as numerous as human history itself.

Works Cited

Benedictow, O.J. (2006). The Caucasus, Asia Minor, the Middle East and North Africa. In, *The Black Death 1346-1353: The Complete History* (pp.60-67). Woodbridge, UK: The Boydell Press.

Bodenhamer, D. J. (2013). Beyond GIS: Geospatial Technologies and the Future of History. In A. Von Lunen, C. Travis (Ed.), *History and GIS: Epistemologies, Considerations and Reflections* (pp. 1-2). New York, NY: Springer.

Dunn, R. (2005). Home. In, *The Adventures of Ibn Battuta: A Muslims Traveler of the 14th Century* (pp. 266-281). Los Angeles, CA: University of California Press Berkeley.

Dunn, R. (2005). Mecca. In, *The Adventures of Ibn Battuta: A Muslims Traveler of the 14th Century* (pp. 65-79). Los Angeles, CA: University of California Press Berkeley.

Dunn, R. (2005). The Maghrib. In, *The Adventures of Ibn Battuta: A Muslims Traveler of the 14th Century* (pp. 27-40). Los Angeles, CA: University of California Press Berkeley.

Dunn, R. (2005). The Mamluks. In, *The Adventures of Ibn Battuta: A Muslims Traveler of the 14th Century* (pp. 41-62). Los Angeles, CA: University of California Press Berkeley.

Halsall, P. (2001). *Medieval Sourcebook: Ibn Battuta: Travels in Asia and Africa 1325-1354: Camels, Hyenas, and Bejas*. Retrieved from Fordham University website: https://sourcebooks.fordham.edu/source/1354-ibnbattuta.asp

Maps.com. (2017, June 12). *World History Silk Road Black Death Features*. Retrieved from http://services1.arcgis.com/VAl453sU9tG9rSmh/arcgis/rest/services/WorldHist_SilkRoadBlackDeath_features/FeatureServere

Mares, D., & Moschek, W. (2013). Place in Time: GIS and the Spatial Imagination in Teaching History. In A. Von Lunen, C. Travis (Ed.), *History and GIS: Epistemologies, Considerations and Reflections* (pp. 59-60). New York, NY: Springer.

Peuquet, D.J. (1999). Time in GIS and Geographical Databases. In *Geographical Information Systems: Principles and Applications. Vol. 1* (pp. 97). London: Wiley.

Von Lunen, A., & Travis, C. (2013). Preface. In A. Von Lunen, C. Travis (Ed.), *History and GIS: Epistemologies, Considerations and Reflections* (pp. v-vi). New York, NY: Springer.